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LOW-DENSITY NONWOVEN FABRIC AND PRODUCTION METHOD AND INSTALLATION THEREFOR AND USES

The present invention relates to nonwoven fabrics and to their production methods and installations and to their applications.

To manufacture hygiene products, such as diapers, adult incontinence pads, sanitary towels, etc., it is desirable to manufacture them from a material having as low a density as possible and a tensile strength as isotropic as possible.

For this, the invention provides a method of producing a nonwoven in which filaments coming from a spunbond unit with a die are deposited as a web having a longitudinal direction onto a conveyor, the web is compressed, perpendicular to the plane of the web, into a compressed web and then the compressed web is subjected to a consolidation operation by blasting it with water jets having a diameter of 50 to 250 microns at a pressure of 50 to 500 bar. According to the invention, the web is deposited onto the conveyor using at least one spunbond unit, the die of which is inclined at an angle of from 10 to 60° and preferably from 20 to 50° relative to the longitudinal direction and preferably using at least two spunbond units, the dies of which are inclined in opposite directions, and the water jets are blasted, with interposition of the web, either onto a metal fabric the threads of which have a diameter of between 0.10 mm and 0.35 mm and which have at most 40 threads per centimeter in the warp direction and 40 threads per centimeter in the weft direction, or onto a microperforated sleeve, the dimensions of the perforations of which are between 50 and 600 microns and preferably between 150 and 500 microns, and which has a number of perforations per cm^2 of between 50 and 200.

Preferably, the threads have a diameter of between 0.18 and 0.30 mm and the number of threads per centimeter in the fabric both in the warp direction and in the weft direction is from 15 to 30.

With these conditions, what is obtained by the method according to the invention is a nonwoven fabric made from filaments, having a density of less than 0.10 g/cm^3 and especially between 0.09 g/cm^3 and 0.03 g/cm^3 and better still between 0.07 and 0.03 g/cm^3, and a ratio of the ultimate tensile strength in

the machine direction to the ultimate tensile strength in the cross direction of less than 1.5, and even less than 1.3 or indeed less than 1.1. A nonwoven fabric according to the invention thus combines isotropy of properties with a very low density, which makes this nonwoven fabric incompatible for manufacturing diapers, either as covering layer in contact with the baby's skin or as an outer textile lining to give a textile appearance. The nonwovens according to the invention may also be used as covering layer for feminine hygiene products, as covering sheets for plants under cultivation in the agricultural field, as filter media for filtering air or gases or liquids, as coating substrates and as wiping products. The nonwoven according to the invention has a better rate of acquisition and a higher rate of spread, which makes it particularly useful for diapers. Furthermore, a liquid diffusion ring on the nonwoven according to the invention is substantially circular, which further increases the useful area for acquisition and absorption of the liquid. In filtration, a larger instantaneous retentivity is found, to the point that only a single layer of the nonwoven according to the invention is equivalent to filter media consisting of four layers according to the prior art. Furthermore, the lifetime of the filter is extended.

For the covering layer of a diaper, it is preferred that the titer be between 1 and 3 dtex and that the weight be between 12 and 20 g/m^2. For the spread layer of a diaper or sanitary napkin, it is preferred that the titer be between 3 and 8 dtex and especially between 3 and 7, and that the weight be between 30 and 50 g/m^2 and 7 dtex, the spread layer thus acting as an acquisition layer. For the layers to ensure sealing along the edges, along the leg cuffs, a titer of between 1 and 3 dtex and a weight of 15 to 30 g/m^2 are preferred. In the agricultural use as sheeting for covering plants, a titer of between 2 and 6 dtex and especially between 3 and 4 dtex and a weight of 15 to 30 g/m^2 are preferred. The same will apply to sheeting for forcing in agriculture. In filtration, it is possible to have very different dtex titers ranging from 1 to 8 dtex, especially with a preference for titers of between 4 and 6 dtex, and a weight of between 30 g/m^2 and 150 g/m^2. For impregnation and coating substrates, such as those used for example in the building and civil engineering fields, and in the manufacture of artificial and synthetic leather, titers of between 1 and 8 dtex, with a preference for titers of between 2 and 6 dtex, are found.

The invention is suitable for uncrimped filaments, which considerably

simplifies the method of production. However, optionally the filaments may also be crimped, although this is not preferred as it complicates the manufacture.

The invention is particularly preferred for nonwovens with a weight of between 12 and 50 g/m^2.

These remarkable properties may be explained by the fact that, by having the spunbond unit inclined, a web is obtained whose filaments are better intertwined, the web thus being more able to withstand, without creating holes, the pressure of the water jets, the filaments of the web being better entangled by the water-jet bonding.

Preferably, the metal fabric is made of steel or bronze and has a thickness of between 0.40 and 0.75 mm. It is most particularly preferred for the metal fabric to have a plain weave, a twill weave or a satin weave.

The first step of the method according to the invention consists in depositing filaments onto a conveyor as a web. The filaments may especially be made of a polyolefin, a polyester, a polyamide, a polyvinyl alcohol, a metallocene, a polylactic acid or any other suitable plastic. The filaments preferably have a titer of between 0.9 and 10 dtex.

They are output from a die at the top of the spunbond unit and then descend vertically down to the conveyor, passing through a device that cools them and draws or attenuates them in a conventional manner except that, according to the invention, it is preferred to use two spunbond units whose dies are inclined, preferably in opposite directions, at an angle of 10 to 60° and preferably 20 to 50° relative to the longitudinal direction of the web, which is the direction in which the conveyor moves and is also called the machine direction. The angles of inclination of the two dies may be different, one of them possibly also being perpendicular to the longitudinal direction of the web.

The second step of the method consists in compressing the web into a compressed web while it is on the conveyor. This compression is carried out by standard mechanical means, especially by making the web pass through the nip between two rolls or by compressing it between the conveyor and a roll.

The third step of the method according to the invention consists in consolidating the compressed web by blasting it with water jets having a diameter of 50 to 250 microns under a pressure of 50 to 500 bar. This involves bonding the web by water-jet entanglement, which is a conventional

process, except that care is taken to make the water jets pass through a metal fabric, the threads of which have a prescribed diameter, the number of threads of which per centimeter in the fabric being prescribed in the warp direction and in the weft direction, or through a microperforated sleeve, as described above.

The diameter of the jets is preferably between 80 microns and 200 microns. In general, the jets are arranged in one row or in several rows, the arrangement in one row being preferred. The distance between two jets of any one row is in general between 0.3 mm and 1.4 mm, and preferably between 0.4 mm and 0.6 mm. The consolidation treatment may also be carried out on several successive drums, each equipped with one or more water-jet injectors, especially when the production rate is very high, for example being 800 m per minute. At these speeds, the use of troughs, attached to the injectors, for recovering the rebounding water jets is particularly useful. In general, these speeds are between 20 m/min and 1000 m/min. In particular, it is possible to combine a fabric drum with microperforated sleeve drum roll.

The metal fabric, termed the outer fabric, may be mounted directly on a rotating support drum, but it may also be mounted on a coarser metal fabric, called inner fabric, consisting of threads having a diameter of at least 0.5 mm, which fabric serves as a draining fabric. The inner metal fabric is thus inserted between the rotating drum and the outer metal fabric, preferably being in contact with them. The drum consists of a fixed hollow cylinder with slots provided around periphery, which slots face the injectors and are intended to extract the water. The fixed drum has, around its periphery, a rotating drum consisting of a rigid permeable support. The drum has a diameter of between 300 mm and 1000 mm and preferably between 500 mm and 900 mm. The water extraction slots opposite the injectors preferably have a width of between 5 and 50 mm and preferably between 15 and 40 mm. The nonwoven fabric made of filaments obtained by the method according to the invention has a high softness. However, if this softness may be dispensed with, it is possible for the other two desired properties, namely a low density and a machine direction strength/cross direction strength ratio close to unity, to be further improved by choosing, as drum, a metal sleeve perforated with holes of between 50 and 600 microns and preferably between 150 and 500 microns in diameter, there being from 20 to 200 holes per cm^2 and preferably 70 to 150 holes/cm^2.

If it is also desired to increase the strength of the nonwoven fabric obtained, the compressed web has to undergo a calendering operation before being consolidated. This calendering operation is carried out in a standard calender at a temperature of 100 to 250°C and preferably 130 to 170°C, depending on the nature of the constituent polymer of the filaments (for example for polypropylene webs, this is preferably carried out between 130 and 180°C), with a web area that has melted of 5 to 40% and preferably 10 to 30% of the total area, it being possible for the points of melting to be circular, oval, rectangular, diamond-shaped or the like.

The calendering may consist in passing the web of thermoplastic filaments between heated rolls. To carry out the invention, it is preferred to use a calender consisting of a smooth roll and an etched roll. The pressure and temperature that are applied by the calender cause spot melting of the web of continuous filaments.

The etching may consist of spots of circular, oval, square, rectangular or even diamond shape. The spots of melting on the surface of the web represent from 2 to 40%, and preferably from 10 to 30%, of the area.

It is also possible to use two etched rolls of the male/female type that undergo synchronized rotation and mutual imbrication. It is also possible to use two smooth rolls.

The calendering is carried out at pressures of between 50 N/mm and 150 N/mm.

The calendering speeds may reach several hundred meters per minute and especially 100 to 800 m/min.

The strength index, expressed as newtons per 50 mm per gram of nonwoven per m^2 is particularly good if the calendering operation is incorporated into the method according to the invention. It may reach 2.8, i.e. 1.5 in the machine direction and 1.3 in the cross direction, while the weight of the nonwoven fabric is between 12 and 150 g/m^2, preferably 12 to 100 g/m^2 and better still 12 to 40 g/m^2. Preferably a strength index of at least 3.5 and better still at least 4.5, or even at least 5.5, may be achieved.

By way of comparison, a conventional 20 g/m^2 nonwoven composed of 100% 1.7 dtex polypropylene, which has been carded and calendered, is sold with a thickness of 0.16 mm, a machine direction tensile strength of 40 N/50 mm and a cross direction tensile strength of 9 N/50 mm, i.e. a machine direction strength/cross direction strength ratio of 4.44. Owing to their

poor mechanical properties, it is not possible to reduce the weight per square meter of these carded and then calendered nonwovens. With nonwovens formed from continuous filaments according to the invention, it is possible to obtain nonwovens that are thicker, stronger, more isotropic and with a lower weight per square meter.

After the consolidation device, for entanglement by means of pressurized water jets, the residual water present in the nonwoven is extracted by suction devices connected to vacuum generators, and then the nonwoven is dried, for example in a through-air oven, or with infrared panels or using microwaves. The final nonwoven obtained has a water content of less than 5% by weight.

Before or after drying, a surfactant may be applied to the nonwoven.

The invention also relates to a nonwoven production installation comprising at least one spunbond unit whose die is inclined at an angle of 10 to 60°, and preferably 20 to 50°, relative to the longitudinal direction, and preferably at least two spunbond units whose dies are inclined, in opposite directions, which deposit filaments onto a conveyor as a web, a device for compressing the web perpendicular to the plane of the web so as to obtain a compressed web, optionally a calender that calenders the compressed web, and then a water-jet device for consolidating the compressed and optionally calendered web by blasting it with water jets having a diameter of 50 to 250 microns and under a pressure of 50 to 500 bar, the installation including a water-jet blasting machine having a metal fabric or a perforated sleeve, as indicated above.

Laboratory tests for measuring thickness, density, strength in the machine direction and strength in the cross direction were carried out according to the ERT standards of the EDANA (European Disposables And Nonwovens Association), namely:

a) <u>thickness</u>:

The specimen is conditioned for 24 hours and the test is carried out at 23°C and at a relative humidity of 50%. The thickness of the nonwoven is measured by measuring the distance between a reference plate, on which the nonwoven rests, and a parallel press plate which applies a precise pressure to the surface subjected to the test. The apparatus consists of two circular horizontal plates fixed to a frame. The upper plate moves vertically. It has an area of about 2500 mm^2. The reference plate has a flat surface with a diameter of at

least 50 mm more than that of the upper plate.

The test piece has dimensions of 180 × 80 mm ± 5 mm for the width and the length. A measurement device is provided that measures the distance between the plates when these are brought close together to the point of applying a pressure of 0.02 kPa.

b) <u>strength and elongation in the machine direction and in the cross direction</u>:

A specimen is conditioned for 24 hours and the test is carried out at 23°C and at a relative humidity of 50%. A tensile testing machine is used for the test, comprising a set of fixed jaws and a set of moving jaws, which move at a constant speed. The jaws of the tensile testing machine have a useful width of 50 mm. The tensile testing machine is equipped with a recorder that allows the curve of the tensile force as a function of the elongation to be plotted. Five specimens 50 mm ± 0.5 mm in width and 250 mm in length are cut, in the machine direction and in the cross direction, from the nonwoven. The specimens are tested one by one, at a constant pull speed of 100 mm per minute and with an initial distance between the jaws of 200 mm. The tensile testing machine records the curve of the tensile force in newtons as a function of the elongation, the maximum point of which is determined.

c) <u>weight per square meter</u>:

A specimen in conditioned for 24 hours and the test is carried out at 23°C and at a relative humidity of 50%. At least three specimens with an area of at least 50 000 mm^2 are cut with a cutting device called a press-cutter. Each specimen is weighed on a laboratory balance having a precision of 0.1% of the mass of the specimens weighed.

d) <u>density</u>:

The density is calculated from the measured thickness and from the mass per square meter:

$$d = g/(t \times 1000)$$

in which d = density in grams per cubic centimeter

g = mass per square meter of the nonwoven;

t = thickness (expressed in mm) of the nonwoven tested.

In the appended drawing given solely by way of example:

- figure 1 is a partial schematic plan view of an installation according to the invention; and
- figure 2 is a complete plan view.

The installation shown in figure 1 comprises two spunbond units 1, 2 having a die 3, 4, respectively, which deposit, on the upper run 5 of an endless belt 5 of a conveyor 6 passing over return, tensioning and guiding rollers 7, a web of continuous filaments which then pass from the left to the right in figure 1 through compacting rolls 8 and 9 before passing through a calender 10 consisting of two rolls and then, via a conveyor 11, onto a water-jet blasting machine. The machine comprises a fixed inner drum 12, onto which is slipped either a hollow cylinder 13 made of metal fabric, the threads of which have a diameter of 0.25 mm with 22 threads per centimeter in the warp direction and 22 threads per centimeter in the weft direction, or a microperforated sleeve, the dimensions of the perforations of which are 200 microns and the number of perforations per cm^2 being 100. The metal fabric has a thickness of 0.50 mm and a satin weave. The web passes over the metal fabric 13 and receives water jets 100 microns in diameter at a pressure of 300 bar via injectors 14.

Figure 2 shows that the longitudinal axis Y, Y' of the die 3 and the longitudinal axis Z, Z' of the die 4 are inclined at an angle a and an angle b, respectively, to the axis X, X', which corresponds to the machine direction but in the opposite sense. Figure 2 shows, after the water jet blasting machine, that a dewatering conveyor 15, a drying oven 16 and a winding device 17 are provided.

<u>Examples</u>:

All the examples 1 to 10 were produced with a 20 g/m^2 spunbond nonwoven produced on a PERFOBOND installation sold by Rieter Perfojet, composed of 1.7 dtex polypropylene filaments. This nonwoven had the feature of having a machine direction strength/cross direction strength ratio of less than 1.5, this being particularly advantageous in many applications. The nonwoven had a thickness of 0.15 mm, a machine direction strength of 39.8 N/50 mm and a cross direction strength of 32.1 N/50 mm. It had a density of 0.133 g/cm^3.

After hot calendering, the nonwoven was treated with water jets on a JETLACE machine sold by Rieter Perfoject, which was composed of a hollow cylindrical drum at the periphery of which various jackets or cylinders rotated. It is on the surface of these rotating cylinders that the filaments were treated with water jets. A water-jet injector was installed on the periphery of the drum and the jets that it delivers were directed toward the cylinder.

The water injection system delivered jets 120 microns in diameter, the jets being spaced apart from one another by 0.6 mm. A vacuum of -800 mbar was applied to the inside of the hollow cylindrical drum by a vacuum generator.

All the tests were carried out at a linear speed of 200 m/min. All the specimens were predried on a conveyor provided with suction slots and then dried in a through-air oven at a temperature of 100°C before being wound up.

Example 1: (comparative example)

The drum was equipped with a cylinder C1 consisting of a perforated stainless steel sheet covered with a bronze fabric made up from threads 0.63 mm in diameter in the warp direction and threads 0.51 mm in diameter in the weft direction. It comprised 9.5 warp threads per cm and 8.5 weft threads per cm.

The injector was supplied with a pressure of 100 bar. The thickness of the nonwoven increased, but its surface was perforated with many holes from 0.4 to 0.5 mm^2 in area. Its handle is softer than that of the untreated nonwoven, but the perforations make it unusable.

Example 2:

The drum was fitted with a cylinder C2 consisting of a perforated stainless steel sheet covered with a metal fabric made of stainless steel consisting of threads 0.11 mm in diameter in the weft direction and threads 0.14 mm in diameter in the warp direction. It comprised 39 warp threads per cm and 36 weft threads per cm.

The strength index $I = (39.8+32.1)/20$ was 3.35, whereas, without treatment, it was 3.59.

The injector was supplied at a pressure of 170 bar. The nonwoven increased in thickness and its handle was softer than the initial nonwoven. It was free of defects and perforations, with $I = 3.3$.

Example 3:

Example 2 was repeated with a pressure of 230 bar. The nonwoven increased in thickness and its handle was softer than the initial nonwoven (i.e. that of Example 1) and softer than that of Example 2. It was free of defects and perforations, with $I = 3.16$.

Example 4:

Example 3 was repeated with a pressure of 300 bar. The nonwoven increased in thickness and its handle was softer than the initial nonwoven and

softer than that of Example 3. It was free of defects and perforations, with I = 2.67.

Example 5: (preferred example)

The drum was fitted with a cylinder C3 consisting of a perforated stainless steel sheet covered with a bronze fabric made up of 0.22 mm diameter threads in the warp direction and 0.23 mm diameter threads in the weft direction. It comprised 25 warp threads per cm and 20 weft threads per cm.

The injector was supplied at a pressure of 170 bar. The nonwoven increased in thickness and its handle was softer than the nonwoven of Example 1 and softer than the nonwovens of Examples 2, 3 and 4. It was free of defects and perforations, with I = 3.42.

Example 6: (preferred example)

Example 5 was repeated with a pressure of 230 bar. The nonwoven increased in thickness and its handle was softer than the nonwoven of Example 1 and that of Example 5. It was free of defects and perforations, with I = 3.39.

Example 7: (preferred example)

Example 6 was repeated with a pressure of 300 bar. The nonwoven increased in thickness and its handle was softer than the nonwoven of Example 1 and that of Example 5. It was free of defects and perforations, with I = 3.

Example 8:

The drum was fitted with a cylinder C4 consisting of a perforated rigid cylindrical sheet covered with a nickel sleeve 0.35 mm in thickness and perforated with holes 250 to 350 microns in diameter, comprising 100 holes per cm^2, the holes being randomly distributed.

The injector was supplied at a pressure of 170 bar. The nonwoven increased in thickness and its handle was softer than the initial nonwoven. It was free of defects and perforations, with I = 3.55.

Example 9:

Example 8 was repeated with a pressure of 230 bar. The nonwoven increased in thickness and its handle was softer than the nonwoven of Example 1 and that of Example 8. It was free of defects and perforations, with I = 3.51.

Example 10:

Example 8 was repeated with a pressure of 300 bar. The nonwoven increased in thickness and its handle was softer than the initial nonwoven and that of Example 9 (however, it was not so soft as the nonwoven of Example 7). It was free of defects and perforations, with I = 3.21.

The results of Examples 1 to 10 are set out in the table below:

This table shows that thickness increases from about 50% to more than 100% are obtained, while still having densities that are very much less than those of the nonwoven of Example 1 and for machine direction strength/cross direction strength ratios that are substantially equivalent.

Example 11:

A 140 g/m^2 nonwoven according to the invention, formed from 1.5 dtex polypropylene filaments, was subjected to a filtration test using sodium chloride particles 0.26 microns in diameter suspended in air. The apparatus was of the TSI CERTITEST 8130 type and the air flow rate through the specimen was 103 l/min. A 77% efficiency and a head loss of 420×10^{-5} bar were obtained.

Using the same apparatus and under the same conditions, a 170 g/m^2 product normally used as filtration medium, consisting of four layers of meltblown, spunbond nonwoven, consisting of polypropylene fiber and polypropylene calendered fiber, was tested. The efficiency was 74% and the head loss was 540×10^{-5} bar.

The nonwoven according to the invention had a better efficiency and a lower head loss, while still having a lower weight per unit area. The nonwoven according to the invention that was used had a machine direction strength of 300 N/50 mm and a cross direction strength of 300 N/50 mm, i.e. a ratio between the two of 1.1. Its thickness was 1.9 mm and its density was 0.074 g/cm^3, with I = 4.5.

Example	Thickness (mm)	Thickness increase (%)	Density (g/cm^3)	MD (machine direction) strength (N/50 mm)	CD (cross direction) strength (N/50 mm)	Loss of strength, MD+CD (%)	Handle
No treatment	0.15	-	0.133	39.8	32.1	-	-
1	0.23	53.3	0.087	37.0	30.1	4.8	-

2	0.22	46.7	0.091	36.3	29.7	5.9	+
3	0.26	73.3	0.077	35.1	28.2	8.6	++
4	0.29	93.3	0.069	29.7	23.8	18.4	+++
5	0.24	60.0	0.083	38.0	30.3	3.6	+++
6	0.28	86.7	0.071	37.5	30.4	4.0	++++
7	0.32	113.3	0.063	33.2	26.8	11.9	+++++
8	0.26	73.3	0.077	39.1	32.0	0.8	+
9	0.29	93.3	0.069	39.3	30.8	2.8	++
10	0.32	113.3	0.063	35.0	29.2	7.7	++

The handle was tested by a panel. The best handle is denoted by +++++, the least good.